EFFECTS OF LOCAL METEOROLOGICAL VARIABILITY ON SURFACE AND SUBSURFACE SEISMIC-ACOUSTIC SIGNALS

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ABSTRACT

We present both seismic and acoustic data collected during recent tests to monitor subsurface activity that show a significant increase in the recorded signal amplitude before and after 36 hrs of steady precipitation to illustrate the effects of meteorological variations on seismic and acoustic signals.

INTRODUCTION

The performance of geophysical sensors is dependent on the chemical and mechanical properties of the geo-environment in which they are deployed. For example, seismic and acoustic sensors are affected by both the mechanical stiffness and temperature, respectively, of their surroundings. Geophysical responses to signals of interest sample the material surrounding the sensor as well as the recorded signals, thus changes to the host material over time must be considered and quantified.

Rapid meteorological changes are some of the most common environmental changes to which emplaced sensors are exposed. The effects of such changes on overall system performance have not been analyzed adequately for seismic-acoustic sensors, primarily because transient meteorological events have not been critically important to the types of long-term deployments performed in the past: sensors were situated in hard-rock as opposed to sedimentary settings. Shorter-duration deployments and smaller system architectures (particularly from longer-stand-off distances) now necessitate detailed *a priori* knowledge of meteorological impacts to system design and performance.

Historically, when sighting a location, sample noise surveys are performed to insure a quiet environment for maximum signal detection. Ideally, seismic sensors are emplaced in a hard rock environment with a low-noise field, ensuring the maximum possible signal-to-noise ratio. Also, access to the site must be relatively unrestricted (without compromising site security), and yet the site must be isolated from potential cultural noise and/or interference.

In tactical situations, such careful site selection is not possible. Sensor location is dictated by the target of interest, not by local geology, and seismic sensors may be placed in geologic terrain that reacts to changing meteorological conditions. The temperature and pressure variations of daily and seasonal meteorological conditions also have severe effects on the acoustic sensors due to direct exposure to the atmosphere. These conditions can vary rapidly, even on the timescale of hours. Propagation from acoustic sources at distances of 10s of kilometers depends on the near-surface meteorological conditions at the time of the event. Unfavorable wind and temperature conditions can create a situation in which acoustic sensors are effectively blind to the source of interest.

Both seismic and acoustic data are known to vary with meteorological changes, but the knowledge is generally empirical and of limited use because of limited availability of observations that capture a natural meteorological event with the same fixed-instrument installation. Since most seismic sensors are installed in hard-rock low-noise areas, there has been no need to understand site responses of less-than-ideal sites. Routine meteorological measurements are sporadic in both space and time and changes in meteorological phenomena are not easily associable with particular events on the recorded data.

We begin by discussing local geologic conditions then present both seismic and acoustic data collected during recent tests to monitor subsurface activity. These data show a significant increase in the recorded signal amplitude before and after 36 hrs of steady precipitation. We conclude by discussing the implications of such strong potential variability on system performance.

SITE GEOLOGY

The general geologic setting consists of various layers of fine grained sediments from surficial wind blown silts and sands to compacted silt and clay bearing layers with varying amounts of gypsum and unconsolidated course to fine sands at the 7 m depth. All sediments are damp below about 1 m (Figures 1 and 2).

The wind blown material is typically very fine and well rounded. This mixture of quartz and probably feldspars and minor other mineral grains becomes extremely hard and essentially cemented at about 30 cm apparently due to precipitating gypsum minerals. This

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layer gives way to between three or four distinct layers of buff or tan layers intermixed with gray green layers of compacted silts with varying amounts of clay sized particles and a fair amount of clay minerals as well.

These layers vary in depth and vertical extent depending on the location within the study area. In the upper layer the gypsum forms veinlets some 5 mm in diameter and spaced quite closely throughout the layer. Some crystals of gypsum up to 3 cm in length have been noted. The lowest levels of sediments typically do not contain distinct gypsum veins or crystals. Figure 3 shows this lateral heterogeneity at a much larger scale.

Figure 1a. Typical strata sequence in the study area.

Figure 2. Typical weathering profiles in the study area.

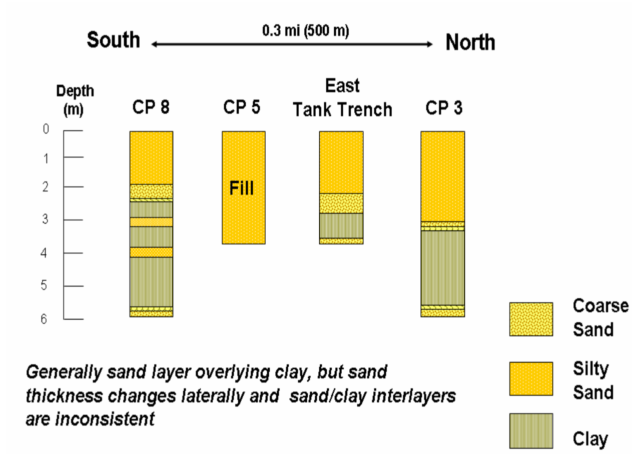

Figure 3. Large scale lateral heterogeneity in the study area.

GEOPHYSICAL DATA

During recent tests to monitor subsurface activity, we collected data that show a significant increase in the recorded signal amplitude before and after 36 hrs of steady precipitation. A 120-channel seismic refraction monitoring system was deployed in a t-shaped formation. The north-south line consisted of vertical component 10 Hz geophones, whereas the east-west line consisted of the above plus 14 Hz horizontal geophones. The source utilized a triggered 6 lb sledge hammer. Figure 4 shows the seismic data collection system schematic as well as the location of the source and receiver discussed in a subsequent section.

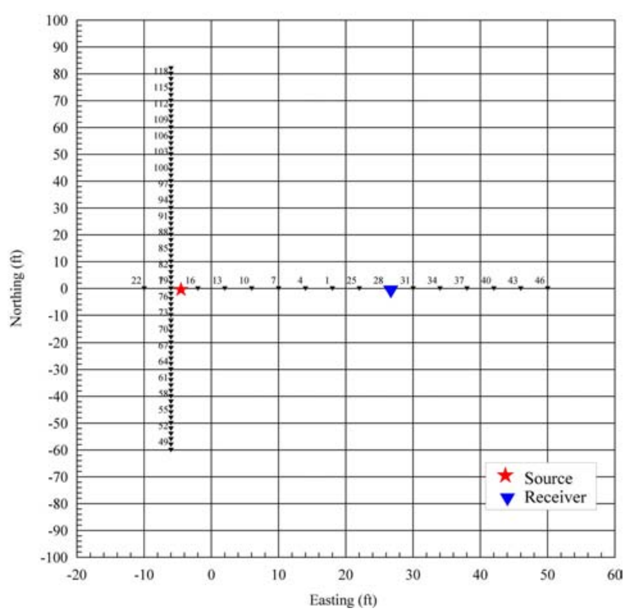

Figure 4a. Seismic sensor map and location of source and receiver.

Figure 4a. Geophones used in the study.

The acoustic sensor consisted of a single microphone with a preamp gain placed at four locations in a line from a larger diesel generator (Figure 5).

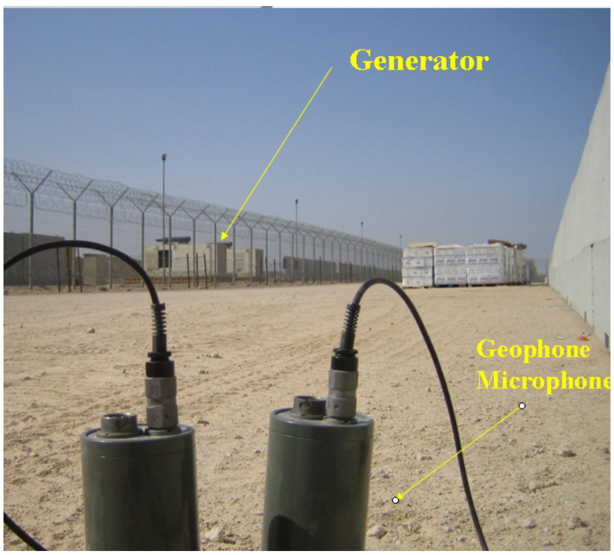

Figure 5a. Acoustic sensor and generator noise source

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Figure 5b. Acoustic sensor with windscreen.

RESULTS

Figure 6 shows the applied to the ambient acoustical noise field and the seismic response before and after 36 of precipitation. In both cases the source/sensor locations were duplicated.

The primary environmental effect observed is the post-precipitation increase in amplitude, which makes these types of signals identifiable at greater distances from the source and effectively improves the range of the instrument. For example, if the purpose of this geophone was to monitor secure facilities or detect activity within subsurface engineered structures such as tunnels or bunkers, then signals that were previously too small to discriminate are now resolvable, and potentially positionable. This enhanced capability would diminish as the near-surface environment dried out. Near-surface variability could create cyclic variations in capability that could be interpreted as false positives and/or instrument failure.

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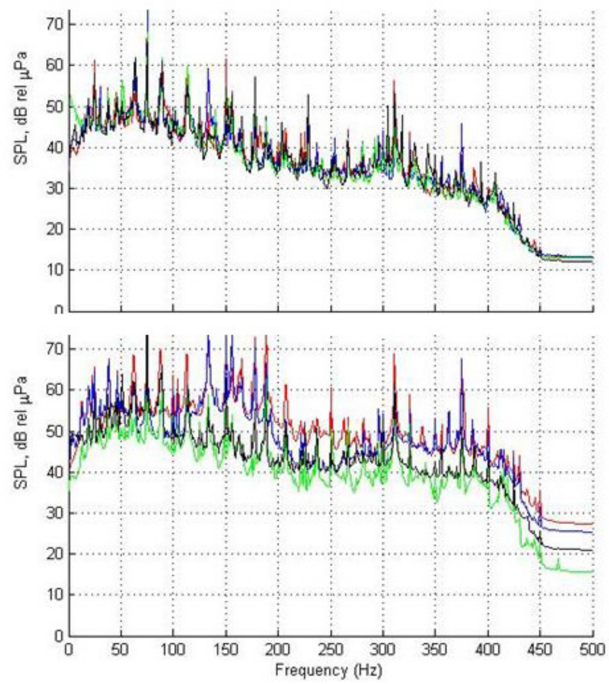

Figure 6. Ambient acoustic noise field before and after 36 hrs of steady precipitation. The different curves represent different locations from a diesel generator lying on (but not bolted to) a concrete pad. The top plot is before, and the bottom trace is after the meteorological event. All the data show an increase in amplitude (10 to15 dB up to 450 Hz) due to the increase in the stiffness of the soil, but the change is variable. Data are from microphones, and were collected before and after 36 hr of precipitation

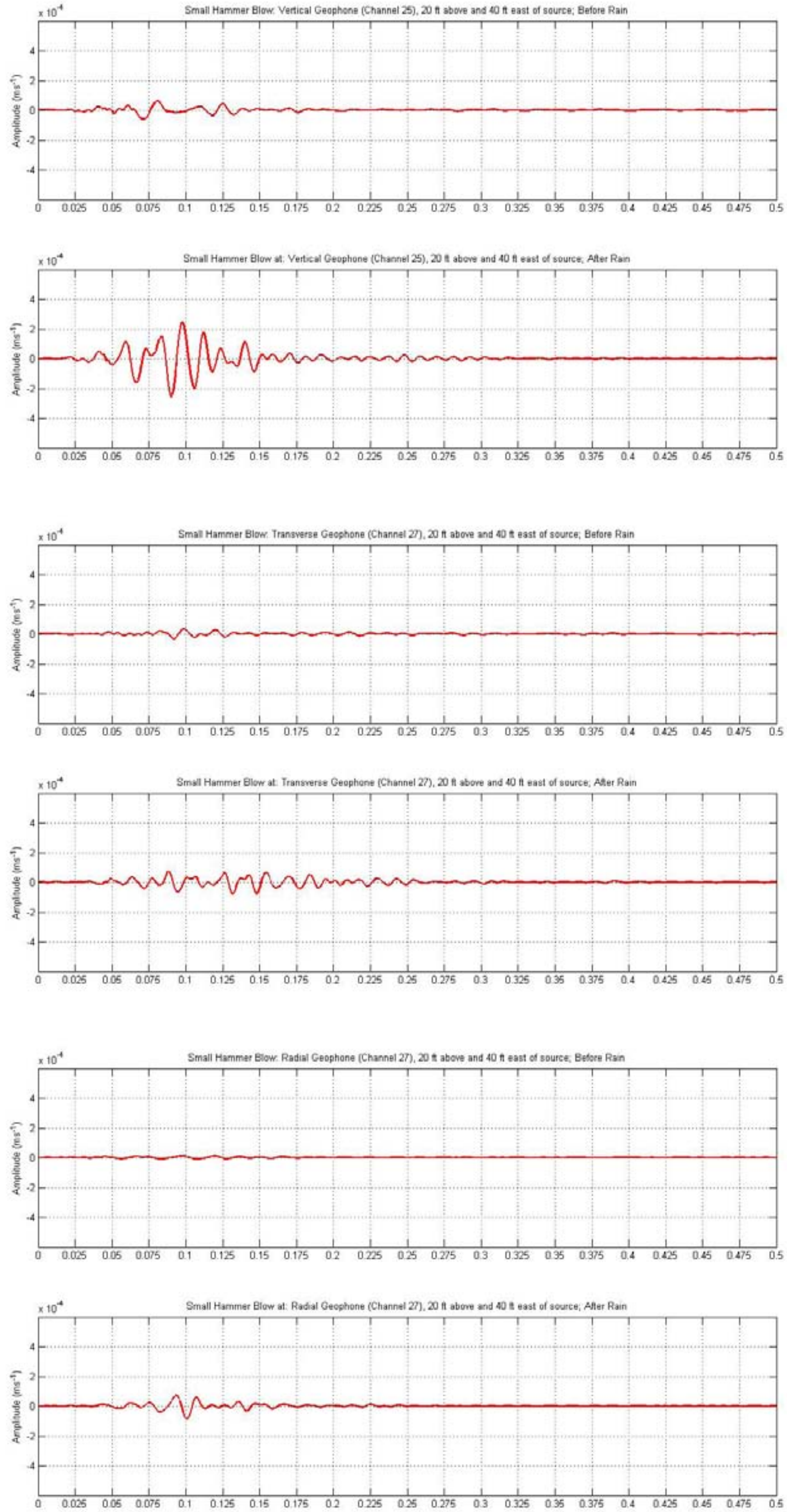

Figure 1. A. Seismic amplitude before and after 36 hrs of steady precipitation. The source was spatially and temporally identical. The topmost subplot is the vertical component, the middle subplot is the north-south component, and the bottom subplot is the east-west component. Within each subplot, the top trace is before, and the bottom trace is after 36 hrs of precipitation.

Another important effect is that the surface/subsurface noise-field is cyclically, or even seasonally, better coupled with the geo-environment. This is particularly important in the battlefield environment where acoustical noise is already highly variable and where sources of cultural acoustics or background noise must be discriminated from the signals of interest

CONCLUSIONS

Meteorological variability can profoundly impact sensor performance. If seismic-acoustic amplitude is to provide real-time monitoring capability, accurate meteorological conditions must be obtained. *A priori* modeling must also be performed to assess and bound potential amplitude fluxuations. In conjunction with an expert system, these types of sensor-soil interactions can generally be accounted for.

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